Of the COMPOSITION *and* PROPORTION *of* CARBON *in* BITUMENS *and* MINERAL COAL. *By* RICHARD KIRWAN, *Eſq*; *L. L. D. F. R. S. and M. R. I. A.*

Read December 19th, 1795.

AN exact knowledge of the component parts of the different ſpecies of mineral coal, and alſo of bitumens (ſubſtances which moſt of them contain;) forms an object of ſome importance not only to the naturaliſt, whoſe views are merely ſpeculative, but to the practical œconomiſt, who wiſhes to extract from each ſpecies all the advantages it is capable of yielding, and to be enabled to compare the various kinds afforded by different countries, in order to obtain and employ that which ſhall on the compariſon appear to him beſt ſuited to his intentions.

IN effect coals are not only applicable to the more uſual purpoſes of combuſtion, an uſe, ſimple as it may appear, attended according to their various ſpecies with a conſiderable difference of calefactive power both in intenſity and duration, but alſo to the production of varniſhes, much more advantageouſly applicable in many inſtances than thoſe extracted from the vegetable kingdom.

dom, as Lord Dundonald has diſcovered and abundantly proved †, and alſo of that chared reſiduum called *Coak*, the only one that can be reſorted to in many caſes, and in moſt ſuperior to vegetable charcoal.

Coals and bitumens are however ſubſtances that reſiſt the uſual modes of analyſis; they elude the action of aqueous, acid, alkaline or ſpirituous menſtruums; and diſtillation, the only mode hitherto uſed, confounds and varies their natural contents.

Reflecting on theſe obſtacles to an exact diſcrimination of bitumens and coals, and of the various kinds of theſe laſt, it occurred to me that partly by combuſtion, and partly by their efficacy in decompoſing nitre, the ſecret of their internal compoſition might poſſibly be unveiled.

1°. *Combuſtion.* I have obſerved that all the ſpecies of ſolid bitumen, properly ſo called, when laid on a red hot iron, burn with a large bright flame, ſmoke and ſoot, leaving none or ſcarce any coaly reſiduum, and only a little aſhes.

That the ſofter bitumens, as maltha, burn in the ſame manner, leaving no coal, but only a little aſhes, and requiring no increaſe of heat for their intire conſumption.

That

† Upon the moſt minute enquiry why coal varniſh is not more commonly employed in paying the bottoms of ſhips, I have been informed the principal reaſon is, that it ſucceeds *too well*—The ſhips not requiring ſuch frequent repair.

THAT *aſphalt* burns with flame and ſoot, but melts and ſwells, and requires for its intire conſumption an increaſe of heat, leaving ſcarce any coal, and but little aſhes.

IT is moreover well known that liquid bitumens contain inflammable air and carbon. That they abſorb atmoſpheric air when long expoſed to it and light. That in conſequence of this abſorbtion they are thickened, blackened and condenſed, firſt into mineral tar, then into mineral pitch or maltha, and laſtly into aſphalt. That almoſt all ſpecies of mineral coal yield more or leſs of both ſpecies of bitumen on diſtillation, leaving a ſhining coaly reſiduum, but that the proportion is variable in every ſpecies, according to the degree of heat applied; that the reſiduum always obſtinately retains a proportion of bitumen, and that conſequently diſtillation, in addition to its other imperfections, is an inſufficient medium whereby to diſcern the proportion of carbon and bitumen, and conſequently to diſcriminate the various ſorts of mineral coal from each other.

2°. *Decompoſition of nitre.* It has long ago been remarked by the juſtly celebrated Macquer† that nitre detonnates with no oily inflammable matter until ſuch matter is reduced to a coal, and then only in proportion to the carbonaceous matter it contains; an obſervation the truth of which will fully appear in the ſubſequent experiments. Hence it occurred to me that ſince in the

† 1 Diction. Chym. 2d Edition, p. 481.

the act of detonnation nitre is always totally or partially decompoſed; and ſince where carbonaceous compounds are employed this decompoſition ariſes ſolely from the mere carbonaceous part, and every thing elſe being equal, is proportioned to the quantity of mere carbon they contain; and ſince moſt ſpecies of coals are compounds of mere carbon and bitumen, as appears by the products of their diſtillation, it ſhould follow, that by the decompoſition of nitre the quantity of mere carbon in a given quantity of every ſpecies of coal may be diſcovered, and this being known, that of bitumen may be inferred, and the other uneſſential ingredients being detected by incineration, the whole contents of coaly ſubſtances might be aſcertained.

THE compoſition of bitumens alſo, as far as relates to their proportion of carbon and oil, may be evidenced in the ſame manner: And here it is to be obſerved that the bitumens I here conſider are thoſe that are found in a dry or ſolid ſtate, and that theſe contain a larger proportion of carbon than the liquid bitumens; for though theſe laſt alſo contain carbon, it being an eſſential component part of all oils, yet this portion does not extricate or educe any air from nitre, nor conſequently contribute to its decompoſition, as the ſubſequent experiments ſufficiently evince, but is conſumed partly by the pure air ſpontaneouſly emitted by nitre during its ignition, and partly by the ambient atmoſphaeric air. Nay, when mineral coal is employed in the decompoſition of nitre, the ſhare which the mere carbonaceous part of the bitumen contained in it contributes to the decompoſition will be found ſo ſmall that it merits no conſideration in the general account.

THE

The firſt ſtep towards carrying this analytic plan into execution muſt therefore be to determine the quantity of pure carbon neceſſary to decompoſe a given quantity of pure nitre. But here many practical difficulties occur which ſhall preſently be mentioned; the moſt perfect method of obviating them was that employed by the ever memorable Lavoiſier: He mixed the pureſt nitre with charcoal alſo purged of the inflammable as well as other airs and water which it uſually abſorbs, in the proportion which, after ſeveral trials, he found requiſite for the entire decompoſition of that ſalt, rammed them into a copper tube, fired them, and continued the inflammation under water, by which means the charcoal was acted on ſolely by the air educed from the nitre, to the intire excluſion of the external air, and this air was educed, ſolely by the ignited charcoal, to the entire excluſion of external heat, advantages that cannot be procured by the uſual mode of effecting this decompoſition; thus he found the proportion of charcoal neceſſary for the entire decompoſition of nitre to be as 1 to 7,57, or in other words, that 13,21 parts charcoal decompoſe 100 of nitre *, and yet even in this experiment I find a ſmall inaccuracy, as he did not take the water employed in mixing the nitre and charcoal into the account, and hence, and for ſome other reaſons, the detail of which would lead me too far, I think the proportion ſhould be as 1 to 7,868 nearly, or that 12,709 charcoal decompoſe 100 of nitre; but the difference is of little importance.

* 11 Mem. Scav. Etrang. p. 626.

THIS mode of experimenting however is inapplicable on the preſent occaſion, the different ſpecies of mineral coal being not ſo readily inflammable as to carry on the combuſtion in this manner. Hence I contented myſelf with the common manner, only uſing ſuch precautions as to render its reſults tolerably uniform, and repeating each experiment ſeveral times.

I EXAMINED the purity of the nitre I employed by nitrated ſilver, and found by the quantity of ſalited ſilver produced that 480 grains of the nitre contained 3,5 grains of common ſalt, 135 grains of muriated ſilver indicating 100 of common ſalt; hence the conſtant quantity of nitre I uſed was 483,5 grains, except in the experiments on bitumens, as I had not enough of them to expend on ſo large a quantity of nitre.

THE nitre was heated barely to redneſs before any coal was projected on it in a wind furnace and a very large crucible; upon this uniform degree of heat much of the uniformity of different experiments on the ſame ſpecies of coal depends.

IN my firſt experiments the coals were reduced to a very fine powder, and then projected on the ignited nitre, but I obſerved that by this method much more of each ſpecies of coal was requiſite to alkalize the ſtandard quantity of nitre than when it was reduced to a coarſe powder, about the ſize of a pin's head or ſomewhat larger, and the reaſon is, that by the force of the exploſion much of the finer powder is carried off without having been

been in contact with the nitre. Hence in the experiments of Mr. Hielm, on the quantities of charcoal of different woods requiſite to alkalize 100 parts of nitre, we find theſe quantities to bear for the moſt part ſome analogy to their ſpecific gravities, being generally ſmaller when the ſpecific gravity of the charcoal is lighter.

Thus, ‡

	Specific Gravity.	Grains requiſite to alkalize 100 Grains of Nitre. Firſt Experiment.	Second Experiment.
Oak coal	0,332	35	30
Birch coal	0,542	22	22
Pine coal	0,280	29	20
Fir coal	0,441	33	25
Coak	0,744	19	

ANOTHER circumſtance of great importance towards procuring juſt and uniform reſults is, that the projections of coal ſhould ſucceed each other without delay as ſoon as the flame ceaſes, for as ignited nitre gives out pure air ſpontaneouſly, and ſo much the more as it is more heated, the acid will be decompoſed and the nitre alkalized by a quantity of coal ſo much the ſmaller as the intervals of projection are longer. From inattention perhaps to this and the laſt mentioned particular, as well as from various conditions of common charcoal, which ſeldom contains leſs than $\frac{1}{12}$ and often $\frac{1}{8}$ of its weight of moiſture and abſorbed air, pro-

 ceeded

‡ Schwed. Abhandl 1781. p. 188.

ceeded the various reſults of different chymiſts with reſpect to the proportion of it neceſſary to alkalize nitre.

It is almoſt ſuperfluous to add that the charcoal ſhould be projected in very ſmall portions. I ſeldom projected more than one or two grains at a time; each operation laſted from twenty to twenty-five minutes nearly. There is always ſome portion of nitre undecompoſed being protected by the ſurrounding alkali; this error is unavoidable but very ſmall. Even the poſition of the crucible in the furnace is not indifferent, for if it be near the flue more coal muſt be employed, which I attribute to the torrent of air which in that caſe affects it and carries away more than when the crucible is nearer to the anterior part of the furnace.

It may perhaps be ſuſpected that this and ſome other incidental errors may be avoided by previouſly mixing the nitre and coal, and projecting the mixture in ſmall portions into a red hot crucible; but not to mention that this method ſuppoſes the due proportion of theſe two ſubſtances to be known, which cannot be known till after the experiment, and alſo that every atom of theſe ſubſtances is in perfect contact with the other ſubſtance, elſe they cannot act on each other; independently, I ſay, of theſe unfounded ſuppoſitions, this mode of experimenting is ſtill more fallacious than the former, as, during theſe projections, a conſiderable proportion of the nitre is ſcattered and diſperſed, and

may

may be ſeen adhering to the ſides of the crucible. This loſs being repeated at every projection becomes at laſt intolerable.

I NOW proceed to relate the experiments themſelves, conducted in the manner I have mentioned. The different ſpecies of coal and bitumen whoſe compoſition I have thus examined were Kilkenny coal, Maltha, Aſphalt, Lancaſhire, Cannel, Slaty Scotch Cannel, Whitehaven, Wigan, Swanſey and Leitrim, ſelecting of each ſort the pureſt ſpecimens, free from pyrites and viſible ſtony matter.

Kilkenny Coal.

ITS colour is *black*, and when freſh broken frequently *violet.*

ITS luſtre 4. metallic. Tranſparency 0.

ITS fracture foliated, the courſe of the lamellæ variouſly and confuſedly directed.

ITS fragments rather ſharp, and often diſcovering between the diſtinct concretions whitiſh illinitions.

ITS hardneſs 7. Specific gravity 1,526.

DOES not burn until wholly ignited, and then ſlowly conſumes without caking or emitting flame or ſmoke. 266 grains of it expoſed to a heat of 27° of Wedgwood in a crucible for five hours

hours did not loſe their luſtre until almoſt $\frac{9}{10}$ of them had diſappeared, and at laſt left reddiſh aſhes amounting to 7,13 grains, nearly 2,7 per cent. Projecting this coal in fine powder on 480 grains of pure ignited nitre, I found the ſalt required 65 grains of the coal to alkalize it, but only 50 grains when in coarſe powder; and in a third experiment, when the crucible was farther from the flue of the furnace, only 49 grains: ſo that I look upon 50 grains as being in round numbers neareſt to the truth. That is the proportion of one part of Kilkenny coal to 9,6 of nitre, or 100 parts of nitre require for their decompoſition 10,416 of Kilkenny coal.

THIS proportion of coal is much ſmaller than that of charcoal in Mr. Lavoiſier's experiment, which we have ſeen to be as 1 to 7,57, or as 13,21 to 100, which I attribute to the advantageous mode in which his experiment was inſtituted, as already explained; whereas in mine and the uſual way, the decompoſition of nitre is promoted by the external heat applied, as well as by the coal, and conſequently leſs of coal is employed.

FROM the experiments of Scheele one *might* be led to infer that the proportions of charcoal and nitre neceſſary to the alkalization of this latter approach ſtill nearer to each other than in Lavoiſier's ſtatement, and conſequently much nearer than in mine; for in his eſſay on plombago he tells us that five parts nitre are *ſufficient* to conſume one of charcoal, and conſequently it ſhould ſeem that one part charcoal ſhould decompoſe no more than five of

of nitre; the conſequence however is not juſt, for undoubtedly five parts nitre would conſume one of charcoal, but it does not thence follow that they would not conſume ſtill more. On the other hand he found that ten parts nitre were *neceſſary* for the conſumption of one part of plombago, whence it follows that one part of plombago decompoſes ten of nitre, otherwiſe nine parts nitre would ſuffice to conſume it, and the tenth would have been unneceſſary, as it acts only as it is decompoſed. Now this proportion approaches very nearly to my reſult, namely, 1 of charcoal to 9,6 of nitre.

HENCE, and ſince Kilkenny coal in the preceding experiments ſhewed no ſign of its containing any thing bituminous, I take it for granted that it conſiſts almoſt entirely of pure carbon; and ſince 50 grains of it alkalize 480 grains of pure ignited nitre, that in all the ſubſequent experiments on other ſpecies of coals or bitumens free from ſulphur and iron, the decompoſition of this ſtandard quantity of nitre will indicate in the quantity of coal neceſſary for that decompoſition, the preſence of 50 parts of mere carbon.

BEFORE I proceed to the recital of other experiments I muſt mention another circumſtance that occurs in making them, which is, that after the inflammation ceaſes a hiſſing noiſe is perceived for a long time, and is increaſed on adding freſh quantities of coal, even when the nitre is ſeemingly decompoſed; this ſeemed

to

to me to ariſe from the decompoſition of the nitrous air or mephitized nitrous acid, of which a portion is always retained by the alkali, and conſequently I paid no attention to it, but always ceaſed adding coal when the inflammation totally ceaſed.

Maltha.

Its colour is dark brown or black.

Its luſtre 0. Tranſparency 0.

Its fracture, *uneven*, tough. Specific gravity 2,070.

It feels ſomewhat greaſy, yields to compreſſion, has a heavy ſmell, acquires a poliſh when ſcraped, does not adhere to the tongue or ſtain the fingers; its flame high and bright, leaving no coal, but only a little aſhes.

Having but a ſmall quantity of this ſubſtance, I on this occaſion uſed only 240 grains of nitre. When it was heated to redneſs I threw on it one grain of *vegetable* pitch; it immediately inflamed, but floated quietly on the ſurface of the nitre, and decrepitated like common ſalt, from the moiſture it contained. The flame was partly *white*, from the action of the air ſpontaneouſly emitted by the nitre, and partly *yellowiſh*, from the action of the ambient atmoſpheric air, but ſteady and unattended with thoſe turbulent guſhes that attend the decompoſition of nitre by carbonaceous ſubſtances.

I THEN gradually projected on it 55 grains of maltha, which was all I had; this burned juſt as the pitch, but was attended with a blacker ſmoak, yet the nitre was ſo far from being alkalized that to produce this effect I was obliged to throw on it 29 grains of Cannel coal. Now 33,5 grains of Cannel coal, if it alone had been uſed, would ſuffice to alkalize 240 grains of nitre, as will preſently be ſeen, therefore the 55 grains of maltha and the one grain of pitch contained no more carbon than 33,5—29=4,5 grains; therefore 100 grains of maltha contain no more than 8 grains of carbon. And as theſe 8 grains of carbon provoked no turbulent eruption of air from the nitre, it is plain they did not contribute to its decompoſition, but were taken up by the air it ſpontaneouſly emitted, and partly by the ambient atmoſpheric air.

Of Aſphalt.

ITS colour is greyiſh black.

ITS luſtre 2.3. greaſy. Tranſparency 0.

ITS fracture perfectly conchoidal.

ITS hardneſs from 7 to 8, very brittle. Specific gravity from 1,07 to 1,165 by my trials. It feels ſmooth, but not greaſy; has no ſmell, except while pounding; does not ſtain the fingers; when heated it melts, ſwells and at laſt inflames, but it requires

for inflammation a higher heat than maltha does, and leaves no coal and ſcarce any aſhes.

Of this bitumen I found 161 grains requiſite to alkalize the ſtandard quantity of nitre. It viſibly educed air from the nitre, for there were eruptions from time to time, I ſuppoſe when the more oily part was conſumed and the carbonaceous laid bare; much of the flame was alſo yellowiſh. Hence 161 grains of aſphalt contain only 50 of mere carbon—that is nearly 31 per cent.

Mr. Thory, burning it in a low heat, found it to leave about $\frac{1}{7}$ of its weight of coal, after melting, ſwelling and inflaming as uſual*; however his aſphalt was not perfectly pure, as he obtained ſulphur from it.

Cannel Coal.

Its colour is black.

Its luſtre common 2. when freſh broken often barely 1. Tranſparency 0.

Its croſs fracture conchoidal. Fragments rather ſharp.

Its hardneſs from 7 to 8. Specific gravity by my trials 1,232. Per Doctor Watſon's 1,273. Does not ſtain the fingers; eaſily kindles

* 6 Crell's Chy. Journ. p. 62.

kindles without melting, and burns with a large bright flame, but of ſhort duration, leaving a large coaly reſiduum; does not cake. 240 grains of it heated until all the coaly part was conſumed left 7,5 grains of reddiſh brown aſhes, moſtly argillaceous, that is 3,12 per cent. 66.5 grains of it were ſufficient to alkalize the ſtandard quantity of nitre. It burned with a large bright flame, except the laſt portion, which was yellowiſh, the pure air of the nitre being then exhauſted. Hence 66,5 grains contained 50 of pure carbon and 2,08 of aſhes; then deducting 52,08 from 66,5 we find the quantity of bitumen equal 14,42; then 100 parts of it contain 75,2 of carbon, 21,68 bitumen of the ſort called maltha, and 3,1 of aſhes.

I TAKE this bitumen to be *maltha* from its quick inflammability and the ſhort duration and brightneſs of its flame, both which properties indicate the moſt inflammable of the bitumens, and whoſe flame is leaſt durable, from its refuſal to cake (caking being a property ariſing from the fuſion of aſphalt) and the difficult combuſtibility of the carbonaceous ſubſtance that remains after the ceſſation of its flame, qualities that counter-indicate *aſphalt*.

Slaty Cannel Coal.

THAT which I employed was from Ayrſhire in Scotland, the only one of this ſort imported to Dublin.

ITS colour is black.

Its luſtre 2. common. Tranſparency 0.

Its fracture partly ſlaty, partly imperfectly conchoidal. Fragments ſharp.

Its hardneſs from 5 to 8. Specific gravity 1,426 by my trials.

It burns like the compact Cannel, but ceaſes ſooner to flame. Does not cake; leaves a ſtony reſiduum. 240 grains of it treated as before mentioned leave 50 of reddiſh grey aſhes, equal 20,83 per cent. From the ſmell that iſſues from it during ignition I am led to think it contains ſome portion of ſulphur.

To alkalize 480 grains of nitre 105 grains of this coal were employed. It burned like the former with a large white continued flame, except the laſt portions. Hence this quantity contained 50 grains of mere carbon; and ſince it alſo contained 20,83 of aſhes, the remainder, viz. 34,15, muſt have been bitumen. Then 100 parts of it contain 47,62 of carbon, 32,52 of bitumen, and about 20 of aſhes. Some deduction however from theſe quantities of carbon and bitumen may be made by reaſon of the ſmall proportion of ſulphur contained in it. This bitumen I take to be maltha and not aſphalt, for the reaſons I mentioned in treating of compact Cannel.

It is from a coal of this ſort that Lord Dundonald extracts his tar, as maltha eaſily diſtills; but it is probably of a better kind, as this ſtony kind exiſts moſtly in Ayrſhire.

By

By his Lordſhip's mode of diſtillation however much ſeems to be loſt during the internal combuſtion. I ſhould think the Prince of Naſſau Saarbruck's method in this reſpect more advantageous. Mr. Sage tells us that by diſtillation he obtained from Cannel coal $\frac{1}{3}$ of its weight of tar†; but Mr. Faujas, who uſes Lord Dundonald's method, obtains from the coal of Deciſe, which ſeems to be of this kind, only 4 per cent. of tar*. Faujas alſo obſerved that this tar is gradually converted into aſphalt by long expoſure to the air, which confirms the difference I have eſtabliſhed between the two bitumens.

Whitehaven Coal.

Its colour is black.

Its luſtre 3. greaſy. Tranſparency 0.

Its fracture plane foliated. Its fragments 2. often diſcovering quadrangular or cubic diſtinct concretions, ſometimes interſected with browniſh red flakes.

Its hardneſs 6. very brittle. Specific gravity 1,257 by my trials. Stains the fingers, particularly when moiſt.

It burns at firſt with a clear flame, and for a long time, but at laſt cakes. 240 grains of it after five hours ſtrong heat left only 4 grains of a reddiſh aſhes, or about 1,7 per cent.

The

† 35 Roz. Jour. p. 387. 27 Roz. Jour. p. 188.

THE ſtandard quantity of nitre was alkalized by 88 grains of this coal. Hence 100 grains of it contain nearly 57 of mere carbon, 41,3 of a mixture of maltha and aſphalt, and 1,7 of aſhes. That it contains both maltha and aſphalt is evident from its flame and caking. The proportion I cannot exactly aſcertain, but moſt probably the aſphalt predominates.

Wigan Coal.

ITS colour is black.

ITS luſtre 3. greaſy. Tranſparency 0.

ITS fracture plane foliated. The lamellæ, ſome uniformly ſome promiſcuouſly directed. In the groſs often flaty. Forms ſeparate concretions, often with bright yellowiſh illinitions.

ITS hardneſs 6. Specific gravity 1,268 by my trials.

IT burns with a bright flame, and quicker than the foregoing, and is leſs apt to cake. 328 grains of it expoſed as the former to a ſtrong heat left 5,13 grains of aſhes, that is 1,57 per cent. 81 grains of it decompoſed 480 grains of nitre. Hence 100 grains of it contain 61,73 of carbon, 36,7 of a mixture of maltha and aſphalt, and 1,57 of aſhes.

IT ſeems to contain a larger proportion of maltha with reſpect to its quantity of aſphalt than Whitehaven coal does.

Swanſey

Swanſey Coal.

Its colour is black.

Its luſtre 2. Tranſparency 0.

Its fracture foliated, but ſome lamellæ being at right angles with the other give it a fibrous or ſtriated appearance. Fragments 2.

Its hardneſs 5. very brittle. Specific gravity 1,357 by my trials.

It burns more ſlowly than the former and cakes.

240 grains of it treated as the former kinds left 8 grains of yellowiſh red aſhes; that is equal 3,33 per cent.

Of this coal 68 grains were requiſite to decompoſe 480 grains of nitre. Then 100 grains of it contain 73,53 of carbon, 23,14 of a mixture of maltha and aſphalt, and 3,33 of aſhes. The aſphalt ſeems to predominate.

Leitrim Coal.

Its colour is black.

Its luſtre when freſh broken 3. Tranſparency 0.

Its fracture foliated. Its fragments 2.

Its hardneſs 6. very brittle. Specific gravity 1,351 by my trials. It ſlightly cakes.

240 grains of it left after three hours expoſure to heat 12,5 grains of reddiſh grey aſhes, that is equal 5,2 per cent.

The decompoſition of the ſtandard quantity of nitre required 70 grains of this coal. Hence 100 grains of it contain 71,43 of carbon, 23,37 of a mixture of maltha and aſphalt, and 5,2 of aſhes.

Newcaſtle Coal.

I had none of this kind of coal, but according to Doctor Watſon's experiment it left on diſtillation a coaly reſiduum amounting to 58 per cent. and hence contained about 40 of a mixture of aſphalt and maltha, in which the former appears to prædominate. Hence it much reſembles the Whitehaven coal, but it evidently contains ſulphur alſo, which that of Whitehaven ſeldom does.

A Synoptical

A Synoptical View of the Contents of Bitumens and different Sorts of Mineral Coal.

100 Parts	Carbon.	Bitumen.	Aſhes.	Specific Gravity.
Maltha - -	8	—	—	2,070
Aſphalt -	31	68	—	1,117
Kilkenny - -	97,3	—	3,7	1,526
Compact Cannel -	75,2	21,68 Maltha	3,1	1,232
Slaty Cannel -	47,62	32,52 Maltha	20	1,426
Whitehaven -	57	41,3 mixt	1,7	1,257
Wigan - -	61,73	36,7 mixt	1,57	1,268
Swanſey - -	73,53	23,14 mixt	3,33	1,357
Leitrim - -	71,43	23,37 mixt	5,20	1,351
Newcaſtle -	58	40 mixt	—	1,271

To theſe reſults I ſhall add a few more, taken from a treatiſe on pit coal lately publiſhed by Signior Fabroni. The Italian coals were examined by himſelf; the French and German by other chymiſts. All by diſtillation.

100 Parts	Carbon.	Bitumen.	Aſhes.	Specific Gravity.
Coal of Halles -	86	12	—	—
of Tudertino -	25	75	—	—
of Cortolla -	45	43	12	1,403
of Macinaia -	60	37	3	1,411
Stony of do. -	12,5	37,5	50	1,666
of Mocaio -	32	35	33	1,403

THESE coals contain very little aſphalt, but chiefly maltha.

MOST coals afford a volatile alkali by diſtillation; this ſeems to me to be rather a product of the operation ariſing from the union of hydrogen and mephitic air, and thus the alkaline baſis of the ammoniacs found on volcanos ſeem to have been formed. Coals alſo afford an acid, commonly the marine, or if pyritous, alſo the vitriolic, more rarely the ſuccinous.

ACCORDING to Mr. Jars, 100 parts of the beſt Engliſh coal give when chared 63 of *coaks* *, but Hielm found the reſiduum of

* 1 Jars, p. 329.

of the beſt Engliſh coals diſtilled to amount to 73 per cent; and Doctor Watſon found the reſiduum of Newcaſtle coal to amount only to 58 per cent. Theſe reſults neceſſarily differ according to the degree of heat applied, the duration of the combuſtion and the variable admiſſion of air. It is plain the bitumen is never totally expelled, at leaſt not until moſt of the carbon is conſumed; but much more of it is expelled by combuſtion than by diſtillation. 3 Watſon, p. 27 and 28.

By Lavoiſier's experiments it appears that equal quantities of water under equal ſurfaces are evaporated, and conſequently equal heats produced by*.

By 403lbs. of coaks	or in meaſure	By 17 of coaks
600lbs. of pit coal		10 of pit coal
600lbs. of charcoal		40 of charcoal
1089lbs. of oak		33 of oak.

The ſame ſuperiority of coaks over charcoal has alſo been obſerved in Germany in other caſes, though with variations in the reſults, plainly ariſing from the different degrees of carboniſication. Thus in Sileſia it was found that in ſmelting of iron ore 92lbs. or one meaſure of coaks was equal to 180lbs. or 3 meaſures

* Mem. Stock. 1781. p. 187.

ſures of charcoal *. Elſewhere it was remarked that one meaſure of coaks were equivalent to 5 of charcoal and 3 of pit coal ‡. Doubtleſs according to the quality of this laſt.

THE cauſes of theſe differences deſerve attention, as the contrary might be preſumed. For in the firſt place I have ſtated that the carbonic part of pit coal is exactly the ſame as common charcoal, and therefore when equal weights of both are employed it ſhould be expected that the calorific effects of both ſhould coincide. In the next place it is known that pit coal and woods containing a large proportion of oil muſt contain a large proportion of inflammable air, and this in combuſtion gives out more heat than an equal weight of mere carbon in the proportion of 3 to 1 †. Therefore it ſhould ſeem that a ſmall quantity of wood ſhould produce the ſame calorific effect as a larger of charcoal.

To remove theſe difficulties I ſhall lay down two poſitions: 1ſt, That the quantity of heat given out by carbon is to that given out by an equal weight of inflammable air (or hydrogen as it is now called) as 1 to 3.

2dly, That to communicate equal quantities of heat, in the caſe now before us, atmoſpheric air muſt have taken up either equal quantities of mere carbon or a quantity of inflammable air equal to one-third of the deficiency.

Now

* 1 Bergm. Jour. 1790. p. 320. ‡ 1 Bergm. Jour. 1792. p. 60.

† 1 Chy. Lavois. p. 104.

Now on examination it will be found that there is ſufficient reaſon to think that this equality or compenſation took place in every inſtance.

THUS, comparing *coaks* and *charcoal*, we muſt obſerve that, according to Doctor Watſon's experiments, charcoal gains 9 per cent. by expoſure to the air for a few days after it is made, by abſorbing partly air and partly moiſture.—3 Watſon, p. 43. And, according to Doctor Prieſtley, 15 per cent. in a month; and this ſeems its *maximum.*—3 Prieſt. p. 417. new edit. But coaks gain only 3 per cent.—3 Wats, p. 46. and ſtill leſs when well burned. Theſe deductions being made, it will be found that the abovementioned 600lbs. of charcoal will be reduced to 510, and the 403lbs. of coak to 391*; the difference then is only 119lbs.

To account for the equality of reſults, notwithſtanding this difference, we muſt conſider that coal containing aſphalt, a much denſer ſubſtance than any vegetable oil, is never ſo thoroughly chared as woods are, as Doctor Watſon has alſo hinted; ſo we have ſeen that Newcaſtle coal is reduced only 72 per cent. though

* Here I muſt mention an error of impreſſion in Mr. Lavoiſier's Memoires, which may deceive: In the text, p. 386, the quantity of coaks is ſaid to be 552, but in the third table, p. 391, it is ſaid to be 403; ſo alſo in the text the quantity of charcoal is ſaid to be 960, and in the table only 600, though the *meaſures* of both are the ſame in both pages. However I found the text wrong and the table right.

though it contains but 58 per cent. of carbon. Coaks therefore always retain ſome remains of bitumen, and conſequently of hydrogen; and in this caſe $\frac{119}{3}$ or 39 parts of hydrogen would compenſate for the defalcation of 119 of carbon.

On the other hand, if we compare the quantities of pit coal and charcoal we ſhall find that 100 parts of ſuch pit coal as is commonly chared, containing at a medium 60 per cent. or more of mere carbon, 600lbs. of it ſhould contain 360 of carbon, or perhaps more; and as it alſo contains much hydrogen, it might be expected to give out a much greater proportion of heat than 391 of coak or 510 of charcoal; but here we muſt take into the account the vaſt quantities of ſmoke and ſoot it throws out, which abſorb a large proportion of its heat, and moreover the bottom of the veſſels heated by it are moſtly covered with ſoot, which conſiderably obſtructs the communication of heat.

The ſame obſervations are in great meaſure applicable to woods. According to Doctor Watſon oak yields but 22 per cent. of charcoal by diſtillation, and ſtill leſs when chared; and beech, according to Wiegleb, only 20 per cent. conſequently 1089 parts of oak yield but 239 of carbon, the remainder of the heat then proceeds from the hydrogen contained in the oils of the wood.

Mr.

MR. LAVOISIER has alſo given the cubic meaſures of theſe combuſtibles, and the times in which each of them produced the ſame effect. For the ſatisfaction of the curious I ſhall expreſs the whole in the following table:

Combuſtibles.	Weight. lbs.	Meaſure. Cub. Feet.	Duration. Hours.
Pit coal	600	10	20
Coaks	403	17	12½
Charcoal	600	40	5
Oak	1089	33	4.4′

HENCE we ſee that if coal produces a certain quantity of heat in a given time, coaks in much ſmaller quantity will produce the ſame effect in little more than half that time, an equal weight of charcoal in one-fourth of that time, and oak in nearly double the weight of the coal in about one-fifth of that time.

THE beſt coal for common uſes ſeems to be that which contains no pyritous, earthy or ſtony matter, and in which the carbonaceous is to the bituminous part in the proportion of 5 to 4, or 6 to 4,5. An equal mixture of maltha and aſphalt is preferable to either ſingly.